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ANALYTICAL STUDY OF SEISMIC BEHAVIOUR OF RCC FRAME WITH SHORT COLUMN EFFECT

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ABSTRACT

Earthquake is a natural disaster which is caused by sudden movement in Earth's crust. Around hundreds of earthquakes are occurring every year in different regions of the world. Out of these, around 2% of the earthquake causes damage to the structure and human lives. From the past studies, it is concluded that the structure which are resting on sloped ground, are most vulnerable to the earthquakes. This is due to variation of column heights on ground floor. Analytical work is carried out of simple 2D frames of different floor heights and different no. of bays is carried out with STAAD Pro software. Different graphs are drawn between its maximum bending moment, axial force, tensile moment, Shear force and compressive force by the use of analytical results. The analysis is done for both plane as well as sloped ground. Later, the sound study on short column effect is done by comparing the results of plane and sloped ground. Most of the studies agree that the short column effect is the major cause for the damage of the structure on sloping ground during earthquake. Some retrofitting technique can also be adopted to reduce the effect.

Key words: Stiffness; Ductility; earthquake; shear force; time period; seismic, short column.

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1. INTRODUCTION

During earthquake, vibrations are generated due to shaking of ground which is termed as seismology. The study of seismology gives the idea of its origination, nature and propagation [3]. The theory which is popularly used to know the fault lines that causes the generation of

earthquake is elastic rebound theory and it is also able to describe the causes of generation of earthquake near the fault lines. Focus of earthquake is always seen near the fault lines. [2][8]

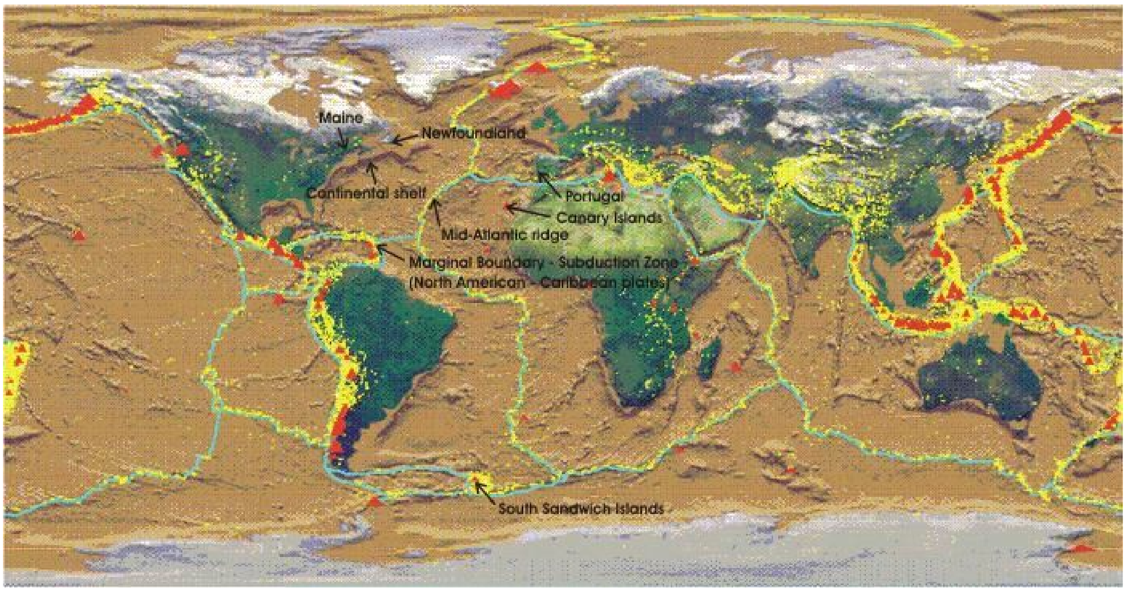

Figure 1 Fault lines and Epicentre aree concentrated along the Fault lines.

Northern and North-Eastern states of India are highly affected by the earthquake. These hilly areas lie in the seismic active belt of Himalayan Range [7]. The above Figure 1 shows the location of epicentre which is concentrated along the fault lines. The prediction of earthquake is not achieved yet and still a lot of work is needed to be done regarding generation of earthquake. Due to industrialisation and increase in population, the growth of the building has been increased in hilly areas. The building in hilly areas has different heights of column on ground floor. Shorter columns attract more lateral forces which lead to damage during earthquake [6].

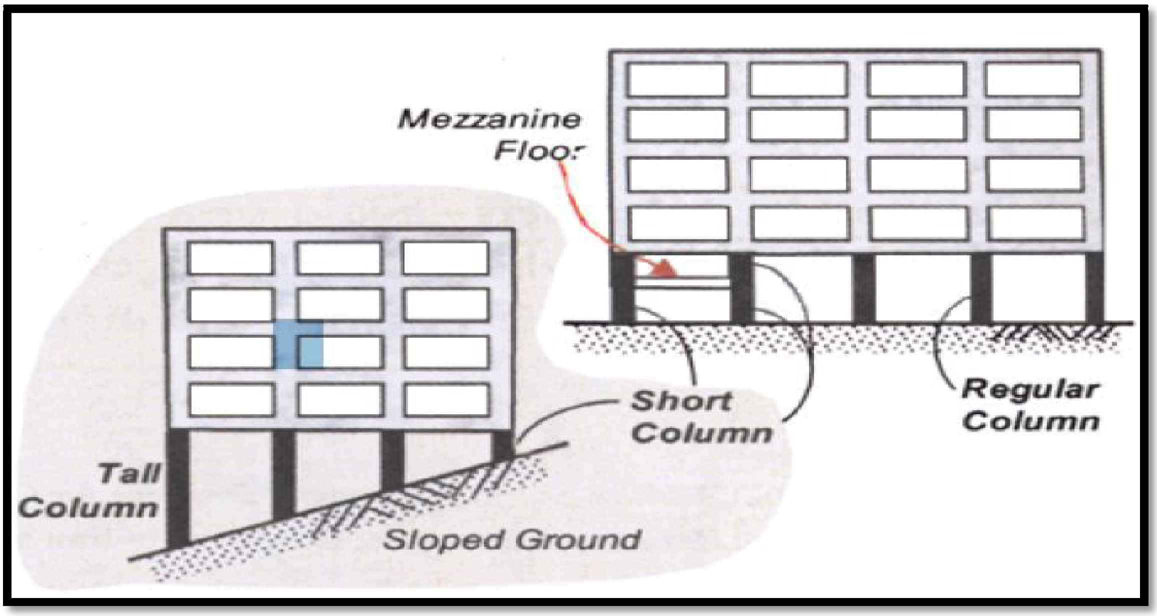

Figure 2 Column resting on Plane and Sloped ground.

The short columns have inferior behaviour than long column because the cross section of both the columns is same and during earthquake, both column will move horizontally by same amount which is described in below figure.

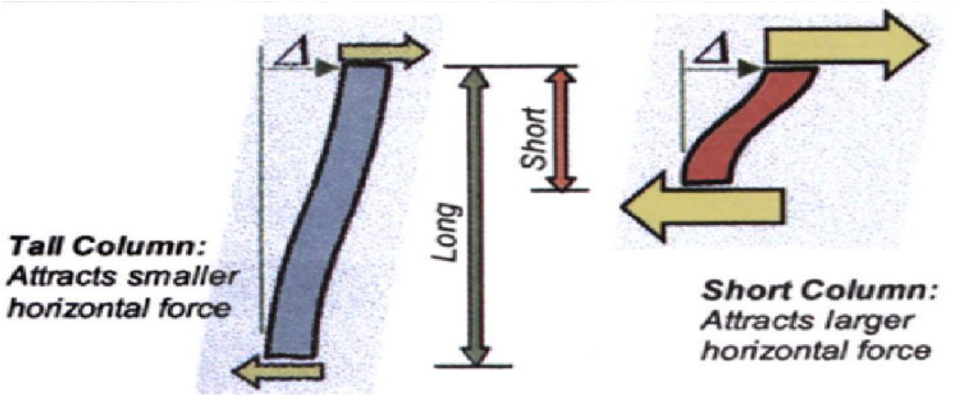

Figure 3 Attraction of force by Short and Long Column.

Short column effect came into existence when short column in a structure is not properly designed and it gets easily damaged during earthquake. Various bracing system can be used to resist the lateral load by transferring the load on sideways and later transferred to the ground [1]. To increase the strength and stability, various retrofitting techniques can also be applied like addition of new shear walls [4]. Ductile detailing can also enhance the property of structural element. Proper ductile detailing are shown in Figure 4 below [4].

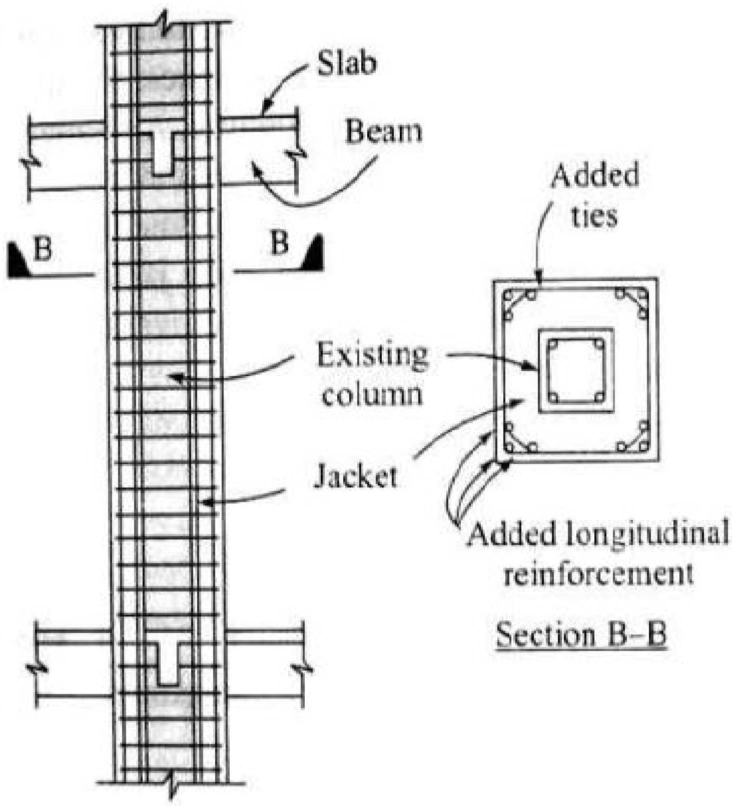

Figure 4 Ductile Detailing

S. Pradeep (2014) studied the seismic behaviour of reinforced concrete framed structures with varying height of column with in one storey with the help of MS-Excel sheet. They have made 20 cases of varying slope by making small increments. Later they compared the result of mode shapes, frequency, time period, base shear and storey drift using STAAD Pro v8i. They have created the model for frames on plane ground as well as for sloped terrain. All the models are modelled with the help of ANSYS 12. After analysing the results shows that the short column in the ground storey fails very easily on a sloping terrain. Shear cracks also

found on the beam column joint of short column. Due to higher ductility in the long column, it attracts lesser lateral force which results the more stable to the long column.[9]

SandeepVissamaneni (2014) has summarizes the buildings which have been damaged due to earthquake in hilly slopes. It is observed that there are irregular arrangements of foundation and are having various structural and constructional problems of the buildings on hill slopes. Due to irregular and unsymmetrical arrangement in both horizontal and vertical direction, stiffness and mass in both directions varies. Due to this, When buildings are subjected to lateral loads, these buildings shows different torsional response. Unequal height of column leads to verify of stiffness on the same storey which results to the damage of short column.[10]

Further the analysis is done for 2-D frame using STAAD Pro. Static and cyclic loading are applied on the frame for both plane as well as sloped ground [5].At first two storey frame is done for analysis work. The frame is made of double bay on a plane ground and sloped ground and later the comparison of the results are done.

2. DETAILS OF WORK

Stage I: The results obtained by STAAD Pro and manually, are compared.

Stage II: 2-D RCC frames are studied under static and dynamic load on plane as well as sloped ground.

2.1. STAGE - I

Analysis of frame shown in below figure are done:

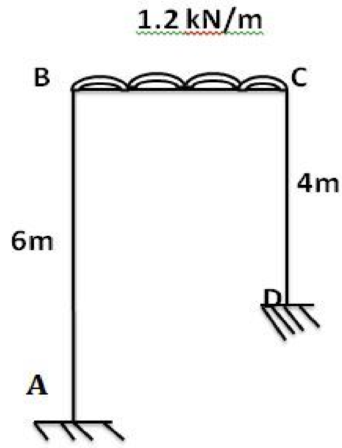

Figure 5 2D frame with short column

Table 1 Calculation of Distribution factor

Node	Member	Relative stiffness	Total relative stiffness	Distribution factor
B	BA BC	I/6 I/3= 2I/6	3I/6	1/3 2/3
C	CB CD	I/3= 4I/12 I/4= 3I/12	7I/12	4/7 3/7

2.1.1. Analysis of Non-Sway

Fixed End moment(FEM)

$M^*_{ab} = M^*_{ba} = M_{cd} = M_{dc} = 0$

$M^*_{bc} = -[1.120 \times 3^2/12] = -0.90$kN-m

$M^*_{cd} = +[1.120 \times 3^2/12] = +0.90$kN-m

Table 2 Moment Distribution for NON-SWAY

	B 1/3	B 2/3	C 4/7	C 3/7	
0	0	-0.90	+0.90	0	0
	+0.30	+0.60	-0.51	-0.39	
+0.15		-0.26	+0.30		-0.20
	+0.09	+0.17	-0.17	-0.13	
+0.05		-0.09	+0.09		-0.07
	+0.03	+0.06	-0.05	-0.04	
+0.02		-0.03	+0.03		-0.02
	+0.01	+0.02	-0.02	-0.01	
+0.22	+0.43	-0.43	+0.57	-0.57	-0.29

So,

Horizontal reaction at A = $\frac{+0.22+0.43}{6} = 0.1083\ kN$

Horizontal reaction at D = $\frac{-0.57-0.29}{4} = -0.2150\ kN$

Net sway force = $0.2150 - 0.1083 = 0.1067\ kN$

2.1.2. Analysis of Sway

Table 3 Moment Distribution for SWAY

		B 1/3	B 2/3	C 4/7	C 3/7		
A	+4.00	+4.00	0	0	+9.00	+9.00	D
		-1.33	-2.57	-5.14	-3.86		
	-0-67		-2.57	-1.34		-1.93	
		+0.86	+1.71	+0.77	+0.57		
	+0.43		+0.39	+0.86		+0.29	
		-0.13	-0.26	-0.49	-0.37		
	-0.07		-0.25	-0.13		-0.02	
		+0.08	+0.17	+0.07	+0.06		
	+0.04		+0.03	+0.09		+0.03	
		-0.01	-0.02	-0.05	-0.04		
Col (a)	+3.73	+3.47	-3.47	-5.36	+5.36	+7.20	

Horizontal reaction at A= $\frac{+3.73+3.47}{6} = +1.20\ kN$

Horizontal reaction at D = $\frac{+5.36+7.2}{4} = 3.1\ kN$

Resolving we have total S=1.20+ 3.14 =4.34 kN

For a Calculation of Sway force of 4.34 kN , the cal. of sway moments will be as per col (a).

Hence, for the actual sway force of 0.1067 kN, the actual sway moment will be $= \frac{0.1067}{4.34}\ x\ col\ (a) moment$

Table 4 Calculation of final Moment

$col\ (a)$	+3.37	+3.47	-3.47	-5.36	+5.36 +7.20	
the actual sway $moment$ $\frac{0.1067}{4.34}\ x\ col\ (a) moment$ Non $sway$ $moment$	+0.09 +0.22	+0.08 +0.43	-0.08 -0.43	-0.13 +0.57	+0.13 -0.57	0.18 -0.29
Final Moments	+0.31	+0.51	-0.51	+0.44	-0.44	-0.11

Horizontal reaction at A = $\frac{+0.31+0.51}{6} = +0.14\ kN$ $\longrightarrow$

Horizontal reaction at D = $\frac{-0.44-0.11}{4} = -0.41\ kN$ $\longleftarrow$

Vertical reaction at A, $V_a = \frac{-0.51+0.44-1.2x3x1.5}{3} = +1.82\ kN$ $\uparrow$

Vertical reaction at D, $V_d = (1.2x\ 3) = +1.78\ kN$ $\uparrow$

2.2. Results Obtained from STAAD PRO

Table 5 Reactions

		Horizontal	Vertical	Horizontal	Moment		
Node	L/C	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	1 DL	0.163	3.597	0.000	0.000	0.000	-0.365
4	1 DL	-0.163	3.066	0.000	0.000	0.000	0.128

Table 6 Beam End Forces

Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	1 DL	1	3.597	-0.163	0.000	0.000	0.000	-0.365
		2	-2.183	0.163	0.000	0.000	0.000	-0.611
2	1 DL	2	0.163	2.183	0.000	0.000	0.000	0.611
		3	-0.163	2.124	0.000	0.000	0.000	-0.523
3	1 DL	3	2.124	0.163	0.000	0.000	0.000	0.523
		4	-3.066	-0.163	0.000	0.000	0.000	0.128

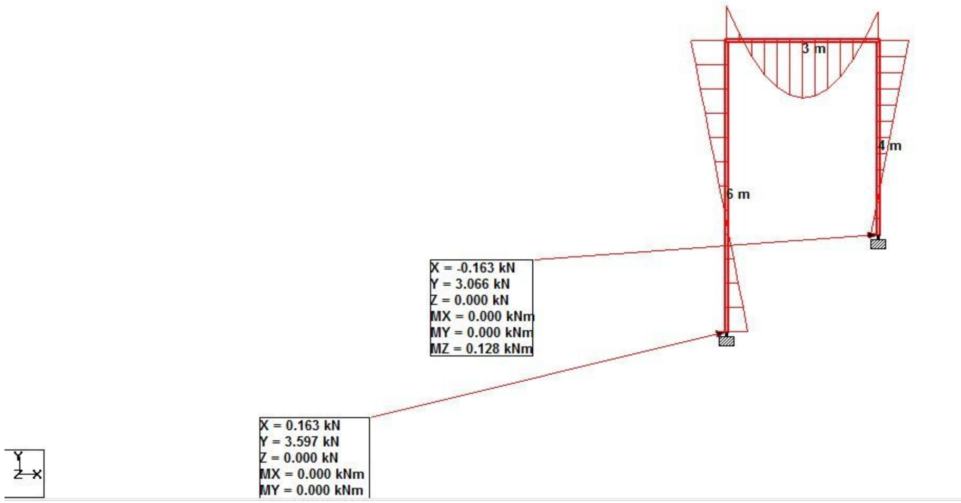

Figure 6 Reaction diagram of 1-bay short column

Table 7 Comparison of result

Final moment (manually) (kN-m)	+0.31	+0.51	- 0.51	+0.44	-0.44	-0.11
STADD Pro moment	-0.365	-0.611	0.611	-0.523	0.523	0.128

2.3. Conclusion from Stage-I

The Analytical and manual results are almost same.

3. ANALYSIS AND TABULATION FOR 2-WAY SHORT COLUMN

3.1. Properties of Member

- All Rectangular Beams:width-450 mm X depth-500 mm
- All Rectangular Columns: width-500 mm X depth-450 mm

3.2. Orientation of Member

Every member: By default

3.3. Material Properties

- Modulus of Elasticity (E) : 22 kN/mm^2
- Density (d) : 25 kN/m^3
- Poisson's Ratio (μ) : 0.17

3.4. Supports

All base columns: Fixed

3.5. Force/Loads

3.5.1. Load case I: Earthquake Force

- Z= 0.16 (Zone)

- SRMF= 5
- I = 1
- Type of Soil- medium
- Frame- RCC
- Ratio of Damping = 0.05
- All load = as per IS1893

3.5.2. Load case II: Dead Load (DL)

- Self-weight of the all member/structure.
- All Beams : 3 kN/m (global Y downward)

3.6. Design of Concrete

- All the load cases are considered.
- Ultimate tensile strength of reinforcement = 415 N/mm^2
- Compressive strength of concrete = 25 N/mm^2
- Cover provided = 20 mm.
- C/C distance between beam = 3 m
- Each storey height
  (a)For plane ground, Storey Height = 3 m
  (b)For sloped ground, Storey Height differs by 1 in 6 with respect to plane ground.
- Length of each beam = 3m
- The dimensions of the supporting column are 0m, 3m and 6m

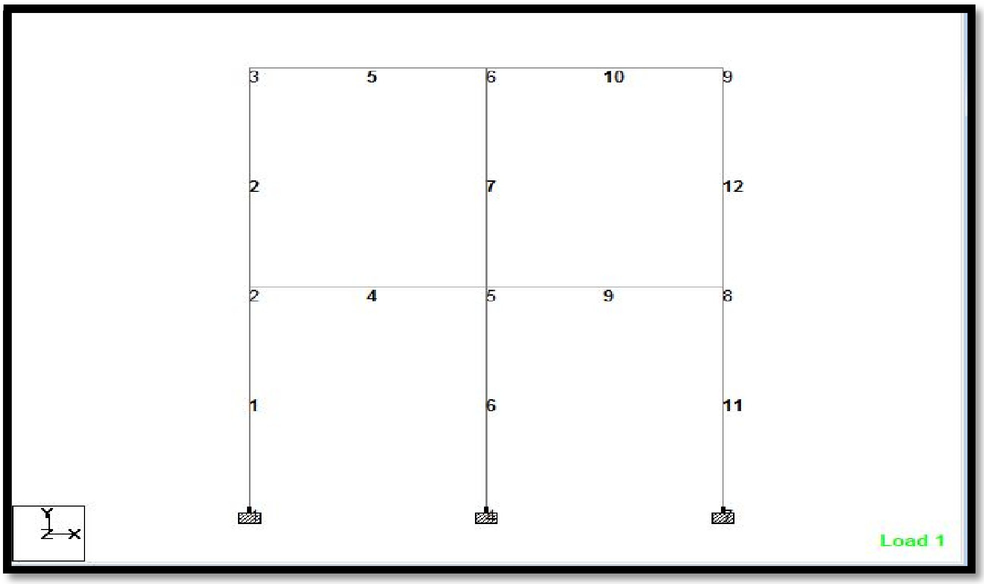

Figure 7 Plane Ground

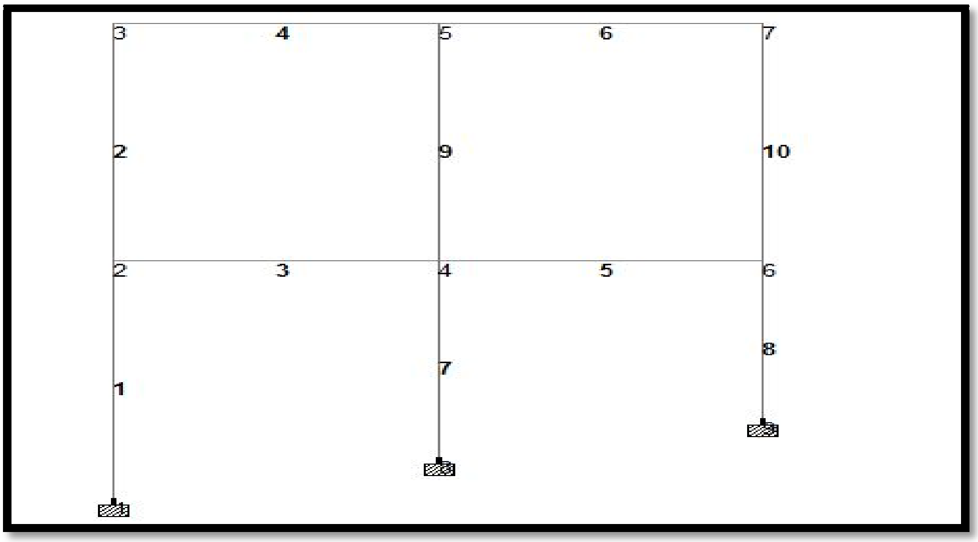

Figure 8 Sloping Ground

Table 8 Analytical results for Two bay Two storey frame on plane and sloped ground.

Beam	Max. Shear Force		Max. Bending Moment		Max. Stress Due to Tension Force		Max.Stress Due to Compression Force	
	Kn		Kn-M		N/Mm^2		N/Mm^2	
	PLANE	SLOPED	PLANE	SLOPED	PLANE	SLOPED	PLANE	SLOPED
1	-0.662	0.771	1.33	-2.434	-0.196	-0.008	0.27	0.278
2	-0.17314	1.138	2.86	1.774	-0.125	-0.009	0.253	0.247
3	-10.498	-1.794	0	2.434	-0.216	-0.007	0.207	0.212
4	-10.832	-1.239	3.97	1.774	-0.206	-0.012	0.221	0.228
5	10.498	2.557	4	3.105	-0.216	-0.014	0.207	0.217
6	10.832	1.191	-2.86	2.615	-0.155	-0.01	0.221	0.228
7	0	1.809	-1.33	-2.542	-0.204	-0.015	0.331	0.337
8	0.662	2.557	0	3.105	-0.196	-0.018	0.27	0.226
9	0	1.684	3.97	2.615	-0.167	-0.005	0.167	0.17
10	1.731	0.986	4	1.686	-0.125	-0.016	0.214	0.245

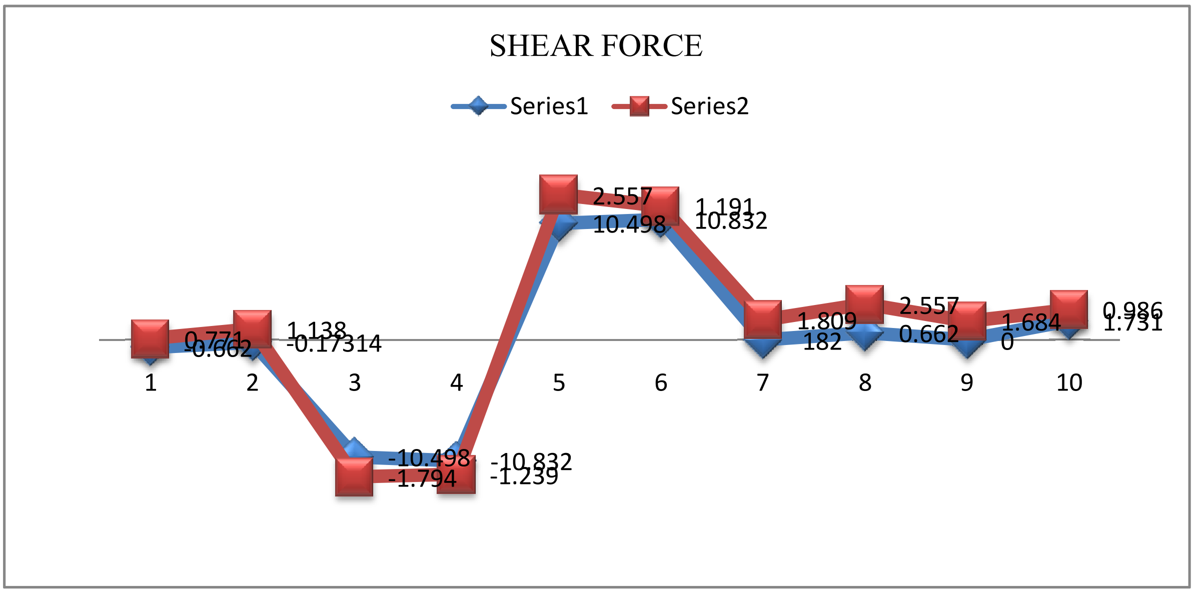

Figure 9 Shear force

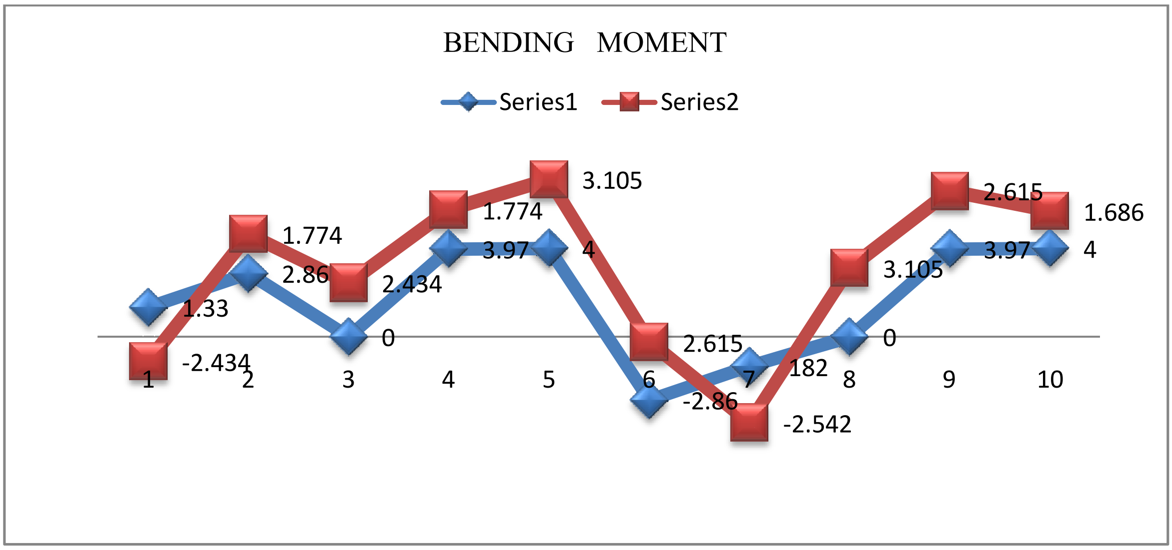

Figure 10 Bending Moment diagram

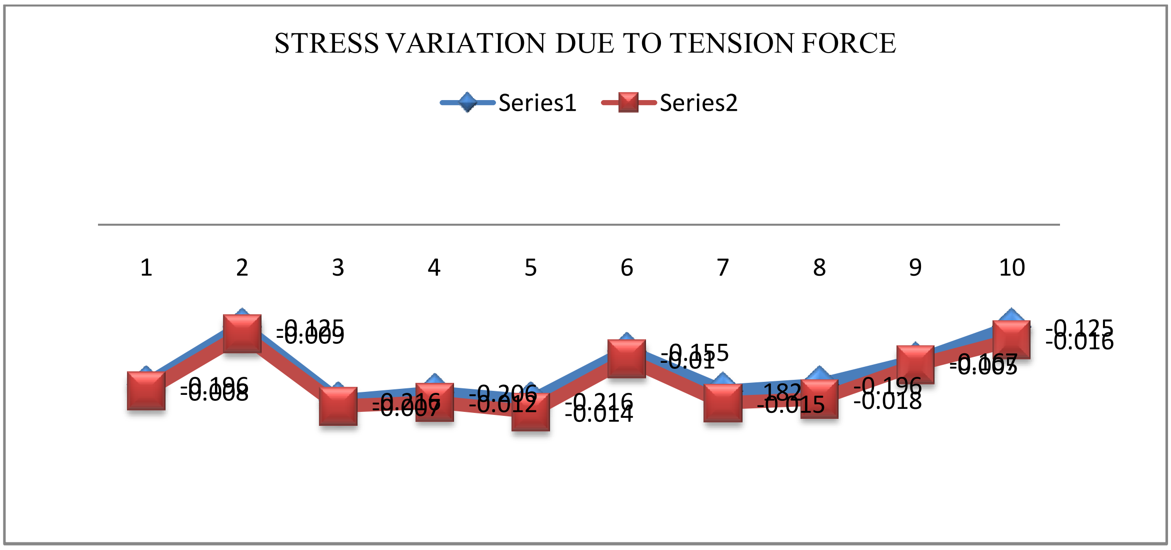

Figure 11 Stress variations due to tension force

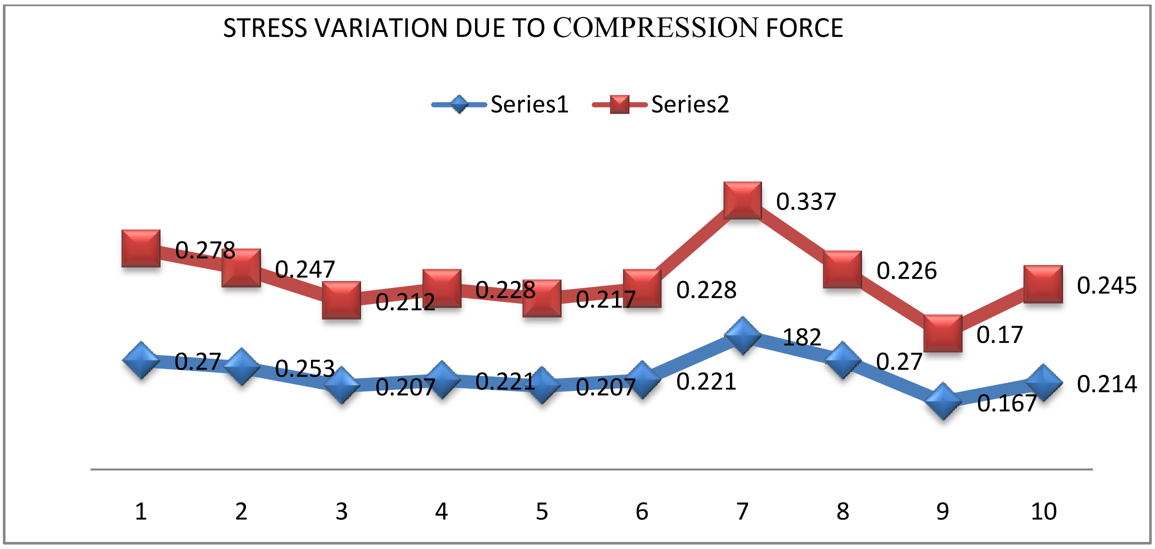

Figure 12 Stress variations due to compression force

4. CONCLUSION

Various studies have been done previously to provide full safety to the structure against earthquake. Now a days, various rules and codes for construction are there to meet the demand of resisting the force which is generated during earthquake. Short column effect causes more and severe damages to the building because it attracts large amount of forces during earthquake. The above two bay two storey frame resting on sloped ground has lesser displacement than same frame resting on plane ground. Shorter displacement leads to more stiffness and cause more attraction forces during earthquake. Time period of frame resting on sloped ground under less compared with same frame on plane ground.

Hence, new regulation in our construction should be adopted to mitigate the loss caused by earthquake. Following factors are there to keep in mind while designing and its construction.

- The construction sites should be selected which have more frequency of occurrence of ground shaking.
- The construction should be high quality according to our IS codes such as IS 1893 and IS 13920.
- According to the analysis, the ductility design should be done for various structural elements.

To increase the safety against seismic forces, these changes in construction and design should be introduced in the structure.

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